CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-121

June 5, 1981

1. Name of fault; location.

Calaveras and related faults, Gilroy and Gilroy Hot Springs quadrangles, southern Santa Clara County, California (see Figure 1).

2. Reason for evaluation.

Part of a ten-year program to evaluate active faults and revise existing Special Studies Zones where warranted (see Hart, 1980).

3. References.

Anonymous, 1975, Black and white aerial photographs, scale 1: 33,600, Code 2640-75, numbers 13-7 to 13-10, 14-4 to 14-7, and 15-1 to 15-4.

Armstrong, C.F, and D.L. Wagner, 1978, Environmental geologic analysis of the Diablo Range Study Area, southern Santa Clara County, California: California Division of Mines and Geology Open File Report OFR 78-11SF.

Bryant, W.A., 1981a, Calaveras and related faults, Morgan Hill and Mt. Sizer quadrangles: California Division of Mines and Geology Fault Evaluation Report FER-122.

__________, 1981b, Calaveras fault and Busch Ranch fault, San Felipe 7.5-minute quadrangle: California Division of Mines and Geology Fault Evaluation Report FER-114.

California Division of Mines and Geology, 1974a, Official map of Special Studies Zones, Gilroy quadrangle.

__________, 1974b, Official map of Special Studies Zones, Gilroy Hot Springs quadrangle.

Clark, M.M., 1973, Map showing recently active breaks along the Garlock and associated faults, California: U.S. Geological Survey Miscellaneous Geologic Investigation Map I-741.

Danehy, E.A., 1976, Feasibility geologic report on 900± acres, east of New Avenue, north of Roop Road, and south of Church Lane, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#306).

__________, 1977a, In-depth geologic report of APN-841-46-35, Crews Road, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#605).

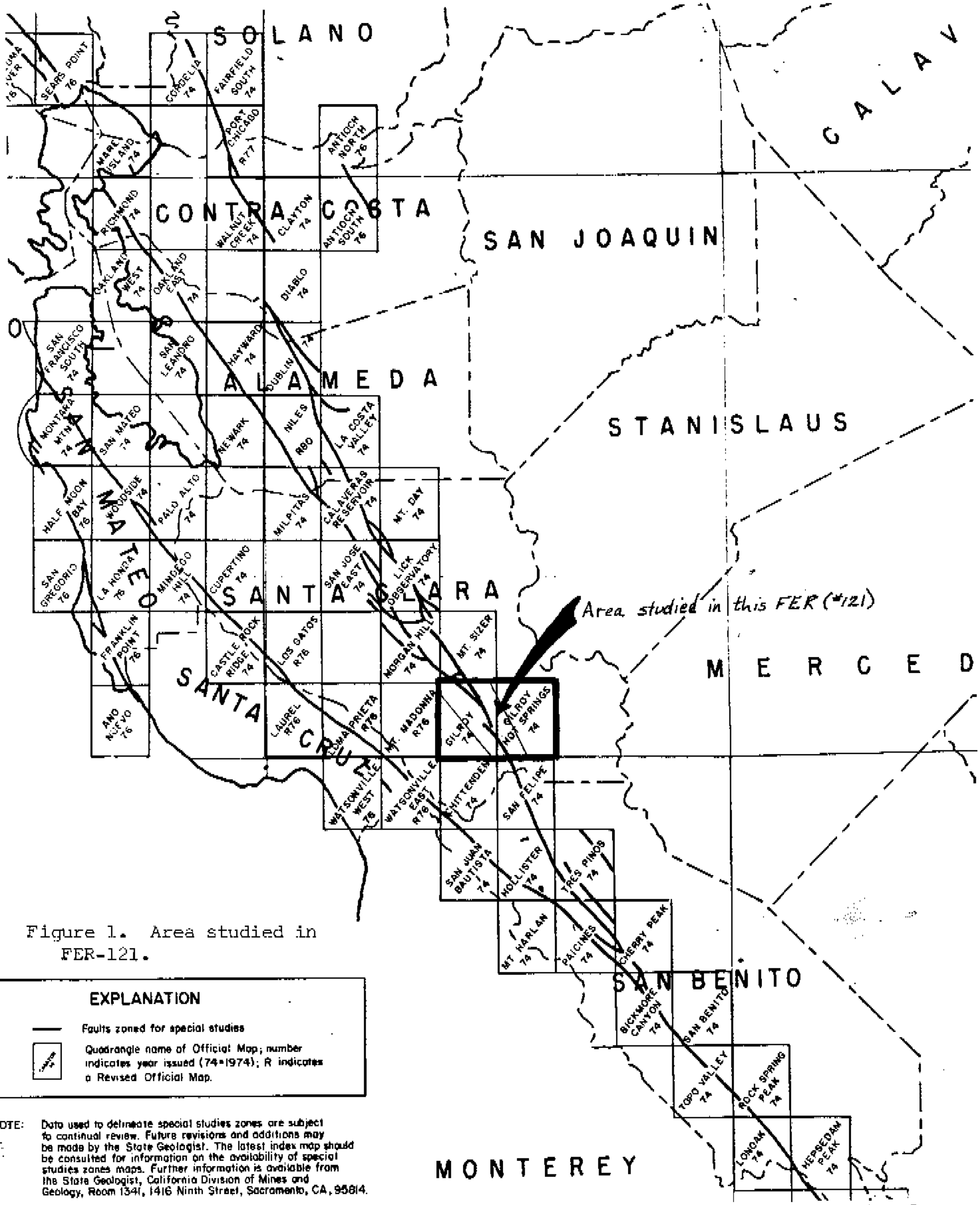

Figure 1. Area studied in FER-121.

EXPLANATION

Faults zoned for special studies

Quadrangle name of Official Map; number indicates year issued (74=1974); R indicates a Revised Official Map.

NOTE: Data used to delineate special studies zones are subject to continual review. Future revisions and additions may be made by the State Geologist. The latest index map should be consulted for information on the availability of special studies zones maps. Further information is available from the State Geologist, California Division of Mines and Geology, Room 1341, 1416 Ninth Street, Sacramento, CA, 95814.

Scale 1:1,000,000

1 inch equals approximately 16 miles

Danehy, E,A., 1977b, In-depth geologic report of APN-841-47-85, Oak Springs Circle, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#699).

__________, 1978a, Concluding feasibility geologic report of Rolling Hills Estates Units 1 & 2, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#1046).

__________, 1978b, Geologic in-depth study of the Golden Hill, Unit 3: Unpublished consulting report filed with the County of Santa Clara (AP# 1045).

__________, 1980, In-depth geologic report for single family residence on APN-898-34-03, Dryden Avenue, Gilroy, California: Unpublished consulting report filed with the County of Santa Clara (AP#1236).

Dibblee, T.W., Jr., 1973a, Preliminary geologic map of the Gilroy quadrangle, Santa Clara County, California: U.S. Geological Survey Open File Map.

__________, 1973b, Preliminary geologic map of the Gilroy Hot Springs quadrangle, Santa Clara County, California: U.S. Geological Survey Open File Map.

Hart, E.W., Bryant, W.A., and Bedrossian, T.L., 1979, Observations of fault rupture associated with the August 6, 1979, earthquake and tabulation of observed data: California Division of Mines and Geology, in-house memo to C.F. Armstrong.

Hart, E.W.,1980, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42.

Helley, E.J., and E.E. Brabb, 1971, Geologic map of late Cenozoic deposits, Santa Clara County, California: U.S. Geological Survey Open File Map (also, San Francisco Bay Region Environment and Resources Planning Study Basic Data Contribution 27).

JCP-Engineers & Geologists, 1979, Feasibility engineering geologic study for 575 acres off Leavesley, Road, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#1012).

Nakata, J.K., 1980, Distribution and petrology of the Anderson-Coyote Reservoir volcanic rocks, California: U.S. Geological Survey Open-File Report 80-1256.

Pampeyan, E.H., 1979, Preliminary map showing recency of faulting in coastal north-central California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1070.

Radbruch D.H., 1968, Map showing recently active breaks along the Hayward fault zone and the southern part of the Calaveras fault zone, California: U.S. Geological Survey Open File Map.

Radbruch-Hall, D.H., 1974, Map showing recently active breaks along the Hayward fault zone and the southern part of the Calaveras fault zone, California: U.S. Geological Survey Miscellaneous Investigations Map I-813.

Terratech, 1978, Geologic feasibility investigation, lands of Austin, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#964).

________, 1979, Fault investigation, lands of Blaettier, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#963).

________, 1980, Combined geologic and geotechnical investigation, Edelweiss Ranch - Lands of Vogt, Santa Clara County, California: Unpublished consulting report filed with the County of Santa Clara (AP#1165).

U.S. Department of Agriculture, 1939, Black and white aerial photographs, CIV series, flight 294, numbers 85 to 94, approximate scale 1:20,000.

U.S. Geological Survey, 1965, Black and white aerial photographs, WRD series, numbers 4462 to 4479, approximate scale 1:6000.

Wagner, D.L., 1978, Environmental geologic analysis of the Diablo Range Study Area II, southern Santa Clara County, California: California Division of Mines and Geology Open File Report OFR 78-12SF.

Williams, J.W., C.F. Armstrong, E.W. Hart, and T.H. Rogers, 1973, Environmental geological analysis of the South County Study Area, Santa Clara County, California: California Division of Mines and Geology Preliminary Report 18.

4. Summary of available information.

The Calaveras fault zone consists of primarily right-lateral, strike-slip faults. During the compilation of the original Special Studies Zones maps of the area (California Division of Mines and Geology, 1974a; 1974b; see Figures 2A and 2B), essentially all faults depicted by various workers either as being recently active or as cutting Plio-Pleistocene or younger deposits, were zoned. Thus, the zoned faults included traces of the Calaveras and Coyote Creek faults, as well as one unnamed fault, delineated by Dibblee (1973a; 1973b), Radbruch (1968; essentially the same as Radbruch-Hall, 1974), and Williams, et al. (1973, then in press). Subsequent to the release of the official SSZ maps, reports by Armstrong and Wagner (1978), Wagner (1978), Hart, et al (1979), and Nakata (1980) were completed, as were several site-specific investigations by consulting geologists (see Table 1).

The criteria for zoning under the Alquist-Priolo Act has been changed significantly since the original SSZ maps of the Gilroy and Gilroy Hot Springs quadrangles were issued. Currently, only those faults that are "sufficiently active and well-defined" are zoned. As used by the Alquist-Priolo Project staff:

> "A fault is deemed sufficiently active if there is evidence of Holocene surface displacement along one or more of its segments or branches. Holocene surface displacement may be directly observable or inferred; it need not be present everywhere along a fault to qualify that fault for zoning.
>
> "A fault is considered well-defined if its trace is clearly detectable by a trained geologist as a physical feature at or just below the ground surface. The fault may be identified by direct observation or by indirect methods (e.g., geomorphic evidence or geophysical techniques). The critical consideration is that the fault, or some part of it, can be located in the field with sufficient precision and confidence to indicate that the required site-specific investigations would meet with some success: (Hart, 1980).

Although evidence of Holocene activity "need not be present everywhere along a fault to qualify that fault for zoning", a reasonable amount of such evidence should be present at several locations along active faults. Should all of the evidence be confined to one small segment of the fault, it may not be active along its entire length and thus may not be entirely zoned. Additionally, Hart (1980) notes:

> "(T)he fact that a fault does not meet these criteria does not mean that it is necessarily inactive or that it is free of ground rupture hazard. Some of the faults not zoned, even some that were not evaluated at all, may have surface rupture in the future. For the most part, such faulting is expected to be minor, both in amount of displacement and in length of surface rupture."

Table 1. Results of investigations by consultants.

FILE #	CONSULTANT; DATE	TRENCHING?	OTHER*	ACTIVE FAULTS FOUND?	COMMENTS
AP#306	Danehy, E.A.;1976	No	L, R, P	Inconclusive	Calls for more work.
AP#605	Danehy, E.A.;1977	No	L, R	Inconclusive	Relies on the work of others re faults.
AP#699	Danehy, E.A.;1977	No	L, R	No	Relies heavily on adj. investigations.
AP#963	Terratech;1979	Yes	L, R, P, SR, M	Did not attempt to determine age of faulting; all faults detected called "potentially active" and setbacks estab	
AP#964	Terratech;1978	No	L, R, P, SR	Yes	All faults, including the main trace of the Calaveras, are shown inferred.
AP#1012	JCP-Engineers & Geologists;1979	No	L, R	Inconclusive	Cites traces of others only. Does not attempt to date faults.
AP#1045	Danehy, E.A.;1978	Yes	L, R, P	No	Cites potentially active fault, but shows it as not cutting old land-slide deposits. See text
AP#1046	Danehy, E.A.;1978	Yes	L, R, P, SR, TP	No	Refutes the existance of several of Armstrong & Wagner's (1978) faults.
AP#1165	Terratech;1980	No	L, R, P	No	
AP#1236	Danehy, E.A.;1980	Yes	L, R, P	No	One potentially active fault may exist on the site.

*Key to other methods used:

L= literature review
R= reconnaissance mapping
P= air photo interpretation
SR= seismic refraction
M= magnetometer surveys
TP= test pits

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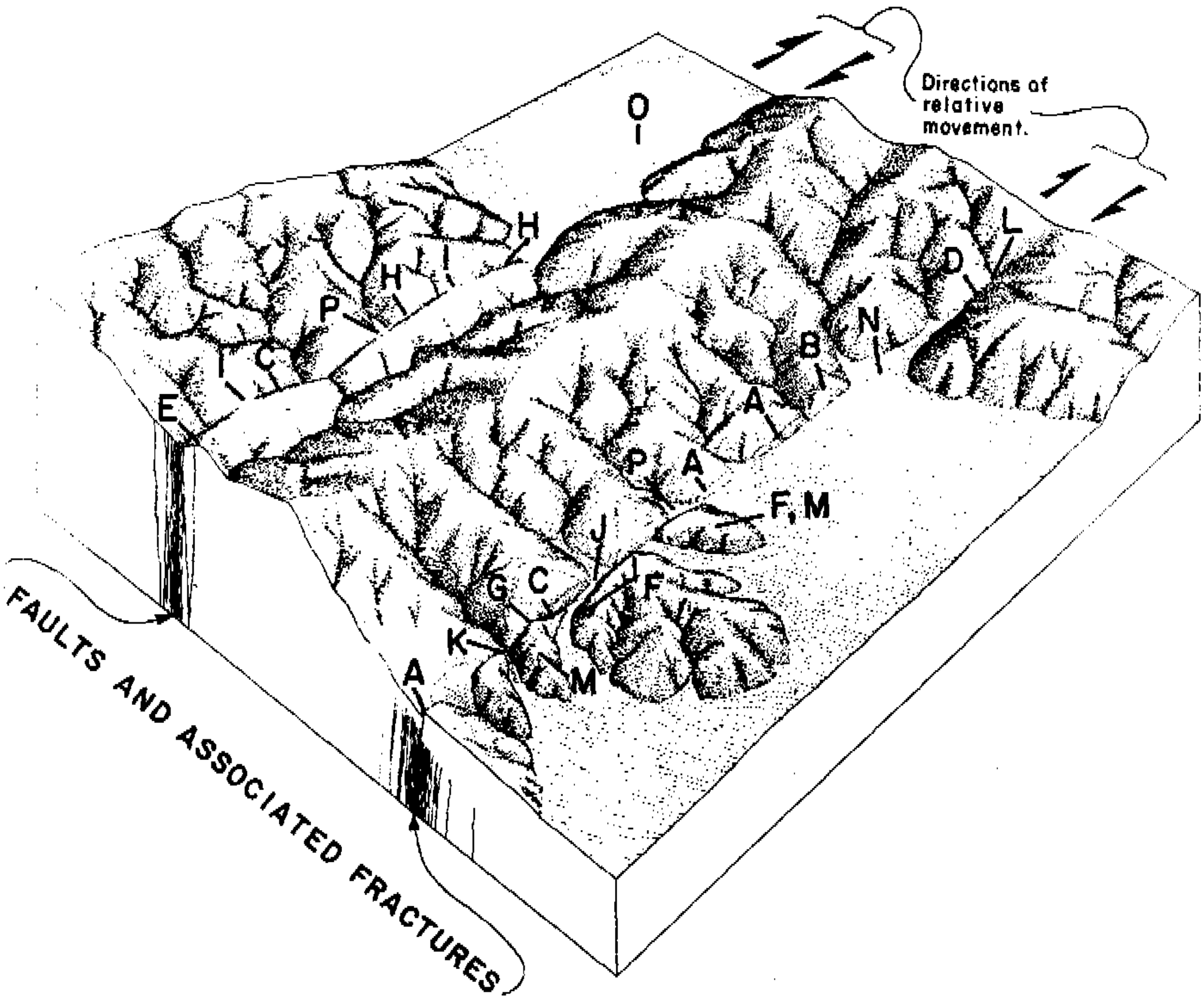
The intent of this FER is to determine which fault traces meet the current zoning criteria and to develop recommendations consistent with the zoning program. In the course of reviewing the literature and the aerial photographs, it became apparent that the intents, methodologies, and products (maps and conclusions) of the various reports reviewed varied greatly. For example, although many of the reports identify recent fault traces, the definitions of the term "recent" vary from Quaternary to Holocene. Thus, although recommendations to avoid potentially active faults have in several cases been made (thus ensuring that Holocene faults are avoided in compliance with the Alquist-Priolo Act), such faults will not necessarily qualify for zoning under the current criteria.

Similarly, the geomorphic criteria used by others to document that Holocene fault movement has occurred differs significantly from that used by Alquist-Priolo Project staff. For example, Armstrong and Wagner (1978) state:

> "If a fault trace exhibits no evidence of historic activity, but is defined by geologically ephmeral, fault-related topograhphic features (see {their} figure 4), the fault is interpreted to be a Holocene fault; that is, it is one which has moved within the Holocene Epoch (the last 10,000 or 12,000 years). If the fault trace offsets or disrupts a soil or geologic unit that can be dated to the Holocene Epoch, this also evidence of Holocene faulting" (Armstrong and Wagner, 1978, p. 20-22).

Figure 4 of Armstrong and Wagner (reproduced herein) as Figure 3 was obtained from Clark (1973). However, Clark does not indicate that these features are conclusive evidence of Holocene fault activity. Indeed he states that some of the features (notches, trenches) can be the product of erosion along a fault zone. The intent of and methodology used by Radbruch-Hall (1974) is also similar to Clarks's. Both were seeking to identify recently active faults.



A. Scarp
B. Faceted ridge
C. Linear gully, trench
D. Linear valley
E. Linear ridge
F. Shutter ridge
G. Notch
H. Hillside valley
I. Bench
J. Offset channel
K. Spring
L. Deflected stream or channel
M. Offset ridge
N. Depression; sag pond when wet
O. Depression (playa lake)
P. Ponded alluvium

FER-121. Figure 3.
(from Armstrong and Wagner, 1978, Fig.4)

Fault related geomorphic features.
(Modified from Clark, 1973.)

In contrast, Pampeyan (1979) attempted to classify faults with respect to their geologic age and also attempted to cite evidence of recent inactivity. Although he largely compiled his map based on the work of others, he used a more specific classification scheme in order to determine the recency of fault movement. Pampeyan clearly considers only sag depressions, and deflected drainages and scarps in Holocene deposits as being geomorphic evidence of Holocene faulting. In essence, only truly ephermal features (such as side-hill troughs, closed depressions) or fault-produced features in Holocene deposits can be used as firm evidence of Holocene faulting. All other features commonly used as evidence of recent faulting are truly only permissive of Holocene faulting, since such features may be created, enhanced, or modified by erosion or even exist for a much longer time because of erosion. To some extent, Armstrong and Wagner (1978) may agree since the legend on their plate 3 lists all fault-related geomorphic features as "indicative of late Quaternary to recent activity."

The methodology used in this FER, parallels to a large extent that used by Pampeyan (1979). However, where the density of small geomorphic features suggestive of Holocene fault movement is high but features conclusive of Holocene movement (as cited above) are lacking because local conditions are such that they either would not form or would not be preserved, such faults may also be recommended for zoning.

Radbruch (1968; and, as Radbruch-Hall, 1974) delineated "recently active breaks" of the Calaveras fault in the study area based on photogeologic and field evidence. Her fault traces and annotated data are summarized on Figures 4A and 4B. Although she does not define the term "recently active," her interpretations are based largely on fault-related geomorphic features generally regarded as indicative of Quaternary fault movement. All of the faults she delineated were used on the

1974 SSZ maps. She shows the Calaveras fault zone as being about 400m or less in width, except adjacent to the southernmost boundary of the study area where the zone is shown slighlty wider. Some of her mapped traces are similar in location to, but differ in detail from, faults shown by Dibblee (1973a; 1973b), Williams, et al (1973), and this investigator (see Figures 4A, 4B, 6A, and 6B). She does not show the Coyote Creek fault or other branch faults located away from the main Calaveras zone.

Geologic maps of the entire study area have been prepared by Dibblee (1973a; 1973b). He did not indicate which faults were recently active, but did clearly label the main trace of the Calaveras fault. Since the original zoning effort was directed at Quaternary faults, all faults that Dibblee depicted as cutting Santa Clara Formation (which Dibblee calls Pleistocene), Plio- Pleistocene basalts, or younger units were zoned (see Figures 2A, 2B, 4A and 4B). From his map, one can infer that the Calaveras fault zone consists of one to four subparallel fault strands, forming a zone about 400 meters wide. Most of the faults in this zone are shown as cutting older alluvium (Pleistocene). The two other faults (which are not named by Dibblee, but which Nakata (1980) considers to be part of the Coyote Creek fault zone) cut only Santa Clara Formation and older units. None of Dibblee's faults are shown as clearly cutting Holocene deposits, although the Calaveras is shown bounding Holocene alluvium in several places. The traces mapped by Dibblee are similar to, but differ slightly in detail from, those of Radbruch-Hall (1974), Williams, et al (1973), and this investigator (see Figures 4A, 4B, 6A, and 6B).

Rogers (in Williams, et al, 1973) also mapped the geology in the vicinity of Coyote Lake. He clearly identified the most recently active trace of the Calaveras fault. This trace coincides with the main trace shown by Radbruch-

Hall (1974), except for minor differences in one area adjacent to Coyote Lake (Fig. 4A). Williams, et al, state that this trace is well marked by sag ponds and other fault-produced geomorphic features. He also depicts several approximately located and inferred faults as cutting early (?) Pleistocene alluvium or old landslide deposits. Some of these additional faults coincide in part with traces mapped by Radbruch-Hall and Dibblee.

Armstrong and Wagner (1978) presented the results of a study directed at the identification of geologic features (mineral resources, geologic unit, faults, landslides, etc.) pertinent to the future development of part of Santa Clara County. As part of their effort to detect recently active faults along the Calaveras fault zone, they mapped more than 26 separate fault strands. Of these fault strands, they identified at least 11 as having had movement along them during Holocene time (see Figure 5). The close spacing, length, continuity, and subparallel pattern of the Holocene faults shown by Armstrong and Wagner is unusual, differing substantially from the mapping of Radbruch-Hall (1968; 1974), Dibblee (1973a; 1973b), Williams, et al (1973), and Nakata (1980) (see Figures 4A, 4B, and 5). It is apparent that the continuity of the individual fault strands was interpreted both from the linear geomorphic features present (these are particularly prominent just south of the Gilroy Hot Springs quadrangle) and the distribution of geologic units. Armstrong and Wagner also reported evidence of fault creep along several faults, based on observed deflections of fence lines. Magnetometer profiling also was used to identify faults.

The zone of Holocene faults Armstrong and Wagner show is about one mile wide. Some of these faults are also shown as being historically active. Armstrong and Wagner also classified other faults as late Quaternary or Quaternary in age. Additional faults were not classified with respect to recency. Because the zone of reported historic and Holocene faulting is so extensive, a special effort was made to review the data on which the age assignments were made and to verify the existance of recently active faults through the interpretation of aerial photographs and limited field reconnaissance. Observations of this investigator are annotated in red on Figure 5. To facilitate the discussion, faults strands of Armstrong and Wagner were numbered (Fig. 5).

In general, their fault classifications appear to be based on minimal data. The methodology they used to classify faults as Holocene differs substantially from that used in this FER in that features considered permissive of Holocene movement (such as saddles and scarps in various geologic units) were the primary evidence they used. The magnetometer profiles appear of questionable value since magnetic anomalies are only suggestive of faults and do not demonstrate fault recency. The fence survey data lacks discussion about how certain they were that the individual offsets they noted due to fault movement, and not to downslope movement or alignment problems during construction or reconstruction. They generally stated that they assumed the fences were built in relatively straight lines, or were reconstructed in alignments "faithful in location to the originals." They also noted areas where soil creep clearly caused a dislocation of the fences, but they avoided discussing the possibility that soil creep might have caused or contributed to the deformation of those fence-lines that fit the pattern of faulting they describe.

In addition to geomorphic and fault creep data, geologic evidence for Holocene fault movement is also presented by Armstrong and Wagner (1978, Plate 1). They depict five faults as cutting Holocene alluvium (faults 2, 3, and 5 near Canada Road, and faults 9 and 11 at the head of Ruby Canyon) (see Figure 5). However, other workers have presented significantly different interpretations. Along fault number 2 within the FER study area, Armstrong and Wagner note a scarp in alluvium.

Nakata (1980) mapped the area northeast of this escarpment as older (late Pleistocene) alluvium, and interpreted the contact as depositional and not a fault. Similarly, Dibblee (1973a; 1973b) and Nakata (1980) interpret the contact between the alluvial valley floor and the upland terrain as depositional in the area north of Godfrey Avenue and not a fault relationship (fault #3 of Armstrong and Wagner, 1980). Helley and Brabb (1971) have interpreted the Valley floor deposits in the area studied by Armstrong and Wagner as being Pleistocene in age. For further discussion of the Armstrong and Wagner data, see sections 5 and 6.

Danehy (1978a) reported he was unable to detect an Armstrong and Wagner (1978) fault trace (fault #4) that they depicted as crossing the site he investigated. He also reported (1978b) finding a fault on another site which he determined was "potentially active." This fault lies near an Armstrong and Wagner trace (fault #5) but differs in detail. Danehy's trench logs clearly show the fault disrupts neither the soil nor old landslide deposits. Danehy (1980) notes Armstrong and Wagner's queried fault (fault #4) along the PG and E pipeline can be explained by other causes and that he does not believe it exists.

The purpose of Wagner's (1978) study was also to identify geologic features pertinent to the future development of part of Santa Clara County. He shows about four northwest trending faults, locally complicated by segments of the Coyote thrust fault, in the northern part of the Gilroy quadrangle (see Figure 4A). He also presented data on the recency of faulting (Wagner, 1978, Plate 2). Instead of classifying faults, however, Wagner depicts geologic and geomorphic evidence in support of recent faulting. He also cites geologic evidence (the age of units not cut) against late Quaternary and Holocene faulting in many locations. Of the geomorphic evidence, Wagner notes (Plate 2) that the features cited are indicative of young, but not necessarily Holocene, faulting. The main traces of the Calaveras fault in the Gilroy quadrangle is east of the area Wagner studied. He did cite one location (site A on Figure 4A) where a shear was observed in colluvium. He concluded that many of the unnamed faults he mapped were active during Quaternary and, possibly, Holocene time. For further discussion of Wagner's data, see section 5.

In 1979, a moderate earthquake occurred in the study area. Hart, et al (1979), examined the area and noted evidence of surface rupture in several locations. Those sites within the study area where such evidence was observed are noted on Figures 4A and 4B.

Nakata's (1980) study was primarily a petrographic study of the area. Several of the faults he shows are similar to those mapped by Dibblee (1973a; 1973b). He also shows two additional faults mapped by Armstrong and Wagner (1978). His faults appear somewhat generalized, for nowhere does he indicate that any unit younger than Plio-Pleistocene Santa Clara Formation is faulted, even along the main trace of the Calaveras fault.

5. <u>Air photo interpretation</u>.

Three sets of aerial photographs (U.S. Department of Agriculture, 1939; U.S. Geological Survey, 1965; and Anon., 1975) were examined for this FER. On the basis of geomorphic features present and the criteria discussed earlier, a narrow zone of recently active (Holocene) faults was delineated (see Figures 6A and 6B). This zone compares well with the faults mapped by Radbruch-Hall (1974, except as earlier noted) and Williams, et al. (1973), and geologic maps of Dibblee (1973a; 1973b) and Nakata (1980). The faults identified partly coincide with several of the Holocene faults of Armstrong and Wagner (1978). In most parts of the study area, it appears that the Calaveras fault consists of a single, active, well-defined fault trace. Locally, however, the fault appears to consist of a narrow zone of two active traces.

USGS (1965) and USDA (1939) photos were checked in an effort to determine how the faults mapped by Radbruch-Hall (1974) compare with the current zoning criteria. Based on the photos interpreted, her inferred trace located west of the main trace and north of Ruby Canyon (Figure 4A) connects benches, saddles, and a possible deflected drainage that are not necessarily the result of recent faulting. All of these features may partly or entirely have resulted from recent landsliding or erosion. No evidence of recent faulting could be found on trend with the inferred fault between these probable landslide areas. Her approximately located traces (short dash) near the southern end of Coyote Lake and east of the main trace are not annotated. These appear to coincide with a linear drainage and general escarpments, but again lack conclusive evidence of Holocene faulting.

Near the southern edge of the study area, Radbruch-Hall depicts several inferred and approximately located traces west of the main (solid line) trace (see Figure 4B). South of the study area, the Calaveras fault bends slightly, and evidence of Holocene movement has been verified along several sub-parallel faults (Bryant, 1981b). Within and just south of Gilroy Hot Springs quadrangle, however, the geomorphic features consist principally of aligned saddles and structurally controlled drainages in Pleistocene and Pliocene deposits (as mapped by Armstrong and Wagner, 1978). Drainages incised in these deposits do not appear deflected, and thus the two western of Radbruch-Hall's postulated faults lack continuity with respect to Holocene fault-produced topography. Near the northern end of the study area, Radbruch-Hall shows two sub-parallel faults passing through Coyote Lake Dam. On the eastern of these traces she reports possible fault creep damage to the spillway. Williams, et al (1973) report that this damage is believed to be landslide caused and not fault caused. Most of these traces lie beneath the dam, the lake, and very recent alluvial deposits within the study area. Because of this, and the dense vegetation to the north of the dam, the aerial photographs covering this area were of limited value. However, some geomorphic evidence permissive of recent faulting was observed on the western trace.

The remaining traces delineated by Radbruch-Hall (1974) generally agree with the most recently active trace of Williams, et al (1973), the Calaveras fault of Dibblee (1973a; 1973b), segments of Armstrong and Wagner's (1978) traces, and the air photo interpretation documented herein (see Figure 6), although her map differs in detail from each of these other references.

The faults mapped by Dibblee (1973a; 1973b, see Figures 4A and 4B) were also checked on the photos. Although segments of the Coyote Creek fault are well defined primarily due to the contrasting hardnesses of the bedrock units, no substantial evidence to support Holocene movement along the fault was noted. The streams crossing Dibblee's Coyote Creek thrust lacked nick points, and did not appear to be offset laterally. Also, except for the fault segments he mapped that coincide with the faults identified on Figures 6A and 6B, all other faults he mapped lacked geomorphic evidence of recent movement.

The zone of most recent faulting identified by Rogers (in Williams, et al, 1973; see Fig. 4A) agrees well with the air photo data (Fig. 6A). The additional approximately located and inferred faults he shows, several of which coincide with faults shown by Dibblee (1973a), lack conclusive geomorphic evidence of right-lateral, strike-slip movement.

Based on the aerial photos interpreted, Nakata's (1980) appears to have generalized the faults he mapped (see Fig. 4A and 4B). The Calaveras fault he mapped only partly coincides with the main trace identified on Figures 6A and 6B. The remainder of the faults he shows are similar to those shown by Dibblee (1973a; 1973b) or Armstrong and Wagner (1978) discussed elsewhere.

The many faults classified by Armstrong and Wagner (1978) as Holocene were reviewed, as well. A copy of their fault classification map (Armstrong and Wagner, 1978, Plate 3), with annotations developed during this study is presented as Figure 5. To briefly summarize, except for segments of faults 2, 3, 5, 9, and 11, most of the fault trends they delineated and classified as Holocene appear to lack features that conclusively demonstrate or are strongly suggestive of Holocene strike-slip movement. Several streams and/or ridges were noted that cross these trends without being deflected sufficiently to be detected on the photos used, which, in effect, precludes major strike-slip displacement Holocene or latest Pleistocene time, at least along some segments of the faults they mapped.

Along fault # 1 (faults are arbitrarily numbered from east to west to facilitate this discussion; see Figure 5) Armstrong and Wagner cite the existence of several offset fences, an offset curb, and a sag pond, all located south of the area studied in this FER. However, north of the offset fences, several drainages incised into Pleistocene terrace deposits, and the ridges between, do not appear offset. No scarps or similar features were noted in the alluvial deposits to the northwest along trend with their fault.

Similarly, Armstrong and Wagner (Plate 3) report an offset fence along fault #2 (Fig. 5) south of the area studied. Within the FER study area, no scarps in Holocene fan deposits were noted, and most drainages did not appear deflected. In the vicinity of Canada Road, Armstrong and Wagner (Plate 1 and 3) depict the fault using a solid line (well defined, accurately located), and indicate a scarp is present in Holocene alluvium. As noted earlier, Nakata (1980) shows an older alluvial deposit in the vicinity of this scarp and does not map a fault along this trend. Based on the photos interpreted, it appears this escarpment lies along the margin of this older deposit, and may be erosional in origin. The fan to the south lacks any scarp, although one could argue that the meandering stream on the northern margin of the fans shows a general right lateral deflection. The banks of this stream are rip-rapped (field check data), and thus could not be examined.

Several deeply incised drainages cross the trend of fault #3 (Fig. 5) without appearing to be deflected. The scarp near Crews Road noted by Armstrong and Wagner (Plate 3) lies along the valley margin, and could well be the result of deposition of fan deposits along a steep hillfront. No scarps or deflected drainages could be detected along the trend mapped where it crosses an old, deeply incised fan near Roop Road.

Fault 4 (Fig. 5) appears to mostly be the main trace of the Calaveras fault in the southern part of the study area, and is marked by a side-hill trench, several closed depressions (ponds), and an offset fence. Two saddles immediately to the north are premissive features, but the main trace appears to step right from fault 4 to fault 5 south of Canada Road. Although Armstrong and Wagner (Plate 3) indicate a shear zone exists south of Canada Road, no features indicative of recent movement were noted in this area on the photos. The drainage adjacent to the road does not appear deflected. To the north, Armstrong and Wagner query this fault. The only evidence they report to support an active fault to the north is an apparently offset fence in Section 35, east of Crews Road. On the USGS (1965) photos, a bulge in the topography is located just downslope of the fence, suggesting that downslope movement has occurred. Armstrong and Wagner's Figure 17 shows that much of the fence line has been distorted, presumably by downslope creep (see Figure 7

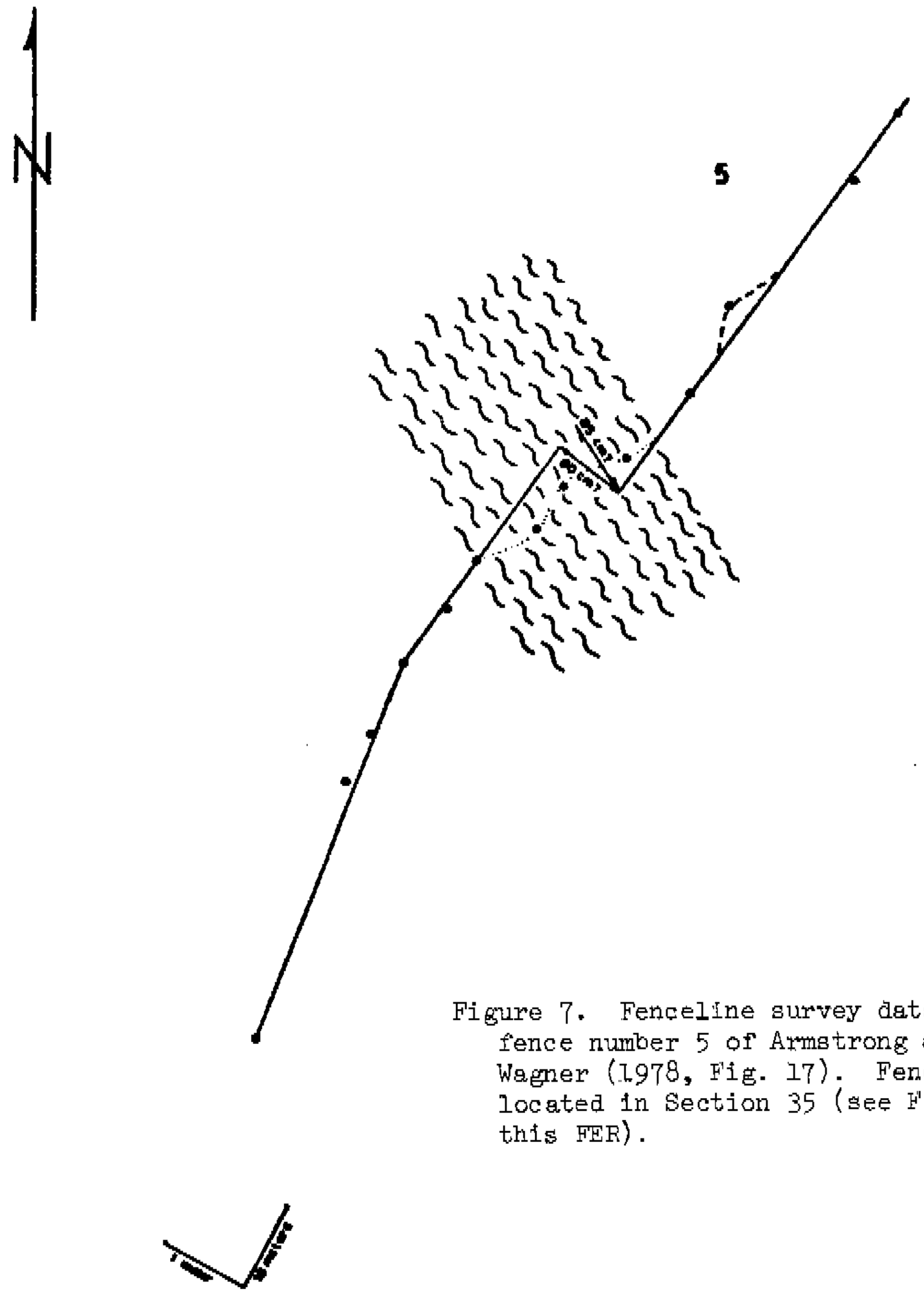


Figure 7. Fenceline survey data for fence number 5 of Armstrong and Wagner (1978, Fig. 17). Fence is located in Section 35 (see Fig 5, this FER).

Surveyed fence post

Original fenceline

Fault-deflected fence

Fence deflected by soil creep

Zone of movement of fault strand

Apparent fence offset

Actual direction and magnitude of fault offset (right lateral)

Querie indicates uncertainty of measurement herein). Drainages to the north and south of the fence do not appear offset, and the fault cannot be traced laterally using geomorphic evidence.

Armstrong and Wagner (Plate 3) report one offset stream (in bedrock) along fault #5 in the SW 1/4 of Section 26. However, except for one closed depression in volcanic terrain, no other evidence to support recent fault activity was noted on their map. This closed depression appears to be on a bench within a large rotational landslide; Ruby Canyon, Oak Creek, and other drainages do not appear offset along this trend. Also, Nakata (1980), who mapped the volcanic rocks in detail, did not delineate a surface fault through this depression, but shows it concealed by Quaternary alluvium or older alluvium (Nakata, p.c., July, 1981).

Armstrong and Wagner (1980, Plate 3) report that faults #6 and #7 have offset a fence and caused ponding of alluvium. A general linear depression containing ponded alluvium was noted approximately where they indicated on Plate 3. No other geomorphic features indicative of a recently active, throughgoing strike-slip fault were noted along fault #6 or fault #7 north of Section 26. For example, Oak Creek does not appear deflected by either faults 6 or 7. The ponded alluvium appear to have resulted from landsliding or lateral spreading of the ridge. The right-lateral offsets of the fences may be due to the release of stored strain, downslope movement of a thick mass of soil, or both (see also, section 6).

Several drainages and ridges along fault #8 (Fig 5, SW 1/4 of Section 36) do not appear deflected. Armstrong and Wagner (1978, Plate 3) cite two offset streams (in pre-Holocene deposits) along fault #12 (see Fig. 5). However, several drainages and ridges along this trend do not appear offset, and no scarp or other fault-related features were noted along this trend in the alluvium at the head of Ruby Canyon. The remainder of their Holocene faults were partly verified by the air photo work. See Figures 5, 6A and 6B for more detail.

Wagner (1978 and p.c.) identified a shear in Holocene colluvium which he reported was evidence for probably Holocene movement along one fault trace (site A on Figure 4A). However, close examination of the USDA (1965) air photos did not reveal any features indicative of recent fault movement (either vertical slip or horizontal slip) along this postulated fault trend. The valley along which the shear is located does not appear to be laterally offset, and the meandering stream which occupies this valley lacks any nick-point or other evidence to support major vertical displacement.

6. Field observations.

One day was spent in the field in order to check and verify some of the data discussed above. Most of this reconnaissance effort was limited to the areas near the paved, public roadways.

As noted above, numerous shears were visible in the road cuts within the study area. Where coherent bedding could be observed in places along Canada Road, it was usually dipping steeply northeastward, and the topography reflects this orientation in many places.

Evidence of historic fault movement was detected in several locations (see Figure 6). Left-stepping en echelon fractures were noted in several locations and coincided with the trend mapped on the air photos. Everywhere the main fault trace crossed paved roads, cracks were always observed, although a left-stepping pattern was not always clear.

The "cracks in asphalt?" reported by Armstrong and Wagner (1978) along fault #11 (see Figure 5) were not found, but left-stepping fractures were present a few hundred feet to the southwest. The three fence offsets they reported north of Ruby Canyon were examined. The fence appears to be clearly offset adjacent to the road (fault #11), but I was not convinced the other "offsets" were due to fault movement.

As noted earler, the area where Canada Road crosses Armstrong and Wagner's (1978) fault #2 was field checked. While the banks of the stream south of the road could not be examined, the meandering nature of the stream and the lack of a scarp across the fan were apparent, suggesting that the deflection may be due to the other than recent faulting.

7. <u>Conclusions</u>.

The Calaveras fault appears to be a well-defined, recently active strike-slip fault (see Fig. 6A and 6B). The fault exhibits clear evidence of major, right-lateral slip during Holocene time. Historic fault rupture has been documented, both as fault creep (Radbruch-Hall, 1974; Armstrong and Wagner, 1978; and this report) and as earthquake associated rupture (Hart, et al, 1979), in several places. There is general agreement as to the location of the main traces of the fault, within the area studied, by Williams, et al (1973), Dibblee (1973a; 1973b), Radbruch-Hall (1974), and this writer. In addition, the main fault traces, partly coincide with segments of Holocene faults of Armstrong and Wagner (1978), although they concluded that the zone of Holocene faulting is much wider and more complex than others show.

Perhaps largely because of differing methodology and criteria used by A-P staff, data developed for this FER does not totally support the conclusions of Armstrong and Wagner (1978) in that conclusive (or even suggestive) evidence for recent faulting along many segments of the faults that they depict as Holocene is lacking. Their reported evidence for fault creep away from the main fault zone, although difficult to prove or disprove, could have been produced by downslope movement. Admittedly, some minor recent fault movement may have occurred along some of these segments, but evidence of systematic offset is lacking. Thus, except for segments of their faults #2, 3, 5, 9, and 11 that coincide with the main trace mapped herein, and parts of faults #6 and 7 that may be Holocene ridge rents (lateral spreading features), the remainder of the traces they mapped do not appear to be sufficiently active and, in some cases, well-defined to warrant zoning.

Radbruch-Hall's (1974) queried fault trace between Ruby Canyon and Coyote Lake does not appear to be a valid, active fault. Instead, it appears that she has connected fault-like features that exist in recent landslide deposits, extrapolating between these deposits even though no similar features existed outside the landslide areas.

Additional faults of Williams, et al, (1973), Wagner (1978), Armstrong and Wagner (1978), Nakata (1980), and Dibblee (1973a; 1973b) lack clear geomorphic evidence of recent (Holocene) fault movement. The two branches of the Coyote Creek fault of Dibblee (1973a), previously zoned under the Alquist-Priolo Act, lack evidence of Holocene activity and are only locally well-defined. Thus, lacking such geomorphic evidence, the likelyhood that a significant, recently active fault exists away from the main active Calaveras fault within the study area is quite low.

8. <u>Recommendations</u>.

Based on the air photo data (figures 6A and 6B), and supported by the maps by Radbruch-Hall (1974), Dibblee (1973a; 1973b), and Williams, et al (1973), the main, active branches of the Calaveras fault should be zoned, as shown on Figures 8A and 8B. Existing Special Studies Zones around all other faults should be deleted. Creep data of Armstrong and Wagner (1978) and this writer should be depicted where these data coincide with the traces depicted. Fault rupture data from Hart, et al

(1979) also should be noted. Evidence is lacking to support zoning of any additional faults in the Gilroy and Gilroy Hot Springs quadrangles.

9. <u>Investigating geologist; date</u>.

Theodore C. Smith

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TCS/map

I have reviewed the air photos and concur with locations of principal active faults as shown of Fig 6A & 6B. I concur with the recommendations.
EWH
8/13/81